

CBM+ Action Group

Prognostics Framework as a Ready, Practical Solution to CBM+



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Purpose

- **Make the AG aware of VSE Corporation:**
 - **Tools**
 - **Previous Work**
 - **Plans to aggressively market our solution to the services and to programs**
- **Communicate that we have a CBM+ solution that is practical, makes sense, works, and is ready for implementation today.**

Related Applications

- **C-130 Gunship Ballistic Computer (TPS)**
- **A-10/KC-135 Turbine Engine Monitoring System (TPS)**
- **Kiowa Warrior Mast Mounted Sight (TPS)**
- **JTIDS (TPS)**

- **Seawolf Submarine Ship Control System**
- **Avitronics Radar Warning Receiver (IETM and ATE)**
- **FAA Wide Area Augmentation System (Embedded and IETM)**
- **F/A-18 Automated Maintenance Environment (AME)**
- **NASA Remote Power Controller (Diagnostician On A Chip)**

Related Applications (Cont.)

- **Navy Total Ship Monitoring (TSM) Program**
 - SPY Radar Final Power Assembly (Microwave Tube)
 - SPY-1 Electronic Cooling Water System
 - Lube Oil System & Pump
- **Navy Battle Group Automated Maintenance Environment Program (BG-AME)**
 - Electronic Dry Air
 - Low Pressure Air Compressor
 - Fuel Service Pump
 - Firemain System

Related Applications (Cont.)

- **Dynamic Reconfiguration Manager for NASA Remote Power Control**
- **Army Future Combat System Gunmount Diagnostics and Prognostics (ADAPT) Program (Changes operating parameters to AVOID failure situations)**
- **Universal Data Acquisition System (UDAS) - replacement for F-16 Crash Survivable Flight Data Recorder**

Major Drivers

Cost Drivers

- ✓ Diagnostic Logic ...

- ...highly complex relationships between symptoms & faults

- ✓ Multiple Fault Scenarios...

- ...are commonplace and heretofar ignored

- ✓ False Return Rates...

- ...impacting spares requirements & ILS/maintenance workload

Operational Driver

- ✓ Mission Capability and Readiness over Time

- Awareness of the status of the system and the support required to accomplish the mission

Operational Needs

- **OPERATOR:** Am I OK? If Not, Why Not? What do I do now? Can I Perform My Mission?



- **MAINTAINER:** Is the System OK? If Not, Why Not? Do I have the spares? How Do I Fix?

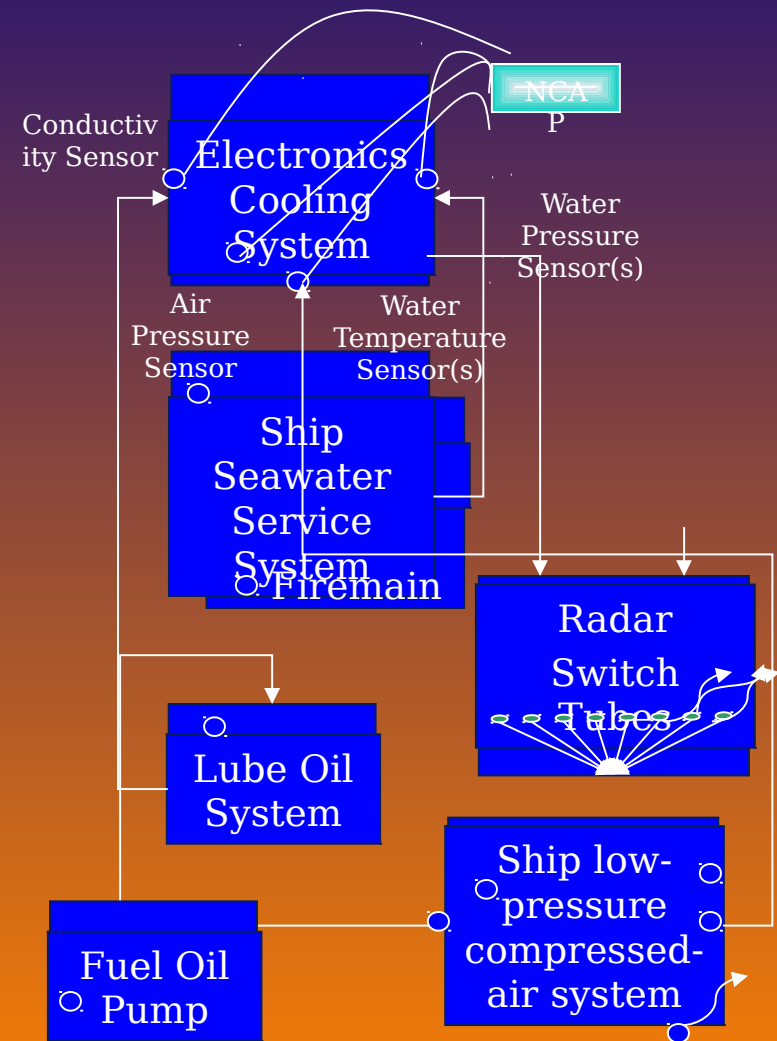


- **COMMANDER:** Which Equipment Should I Deploy for this Mission? Will Equipment Health Impede Mission Success? When Should Maintenance Be Performed?



Current Posture

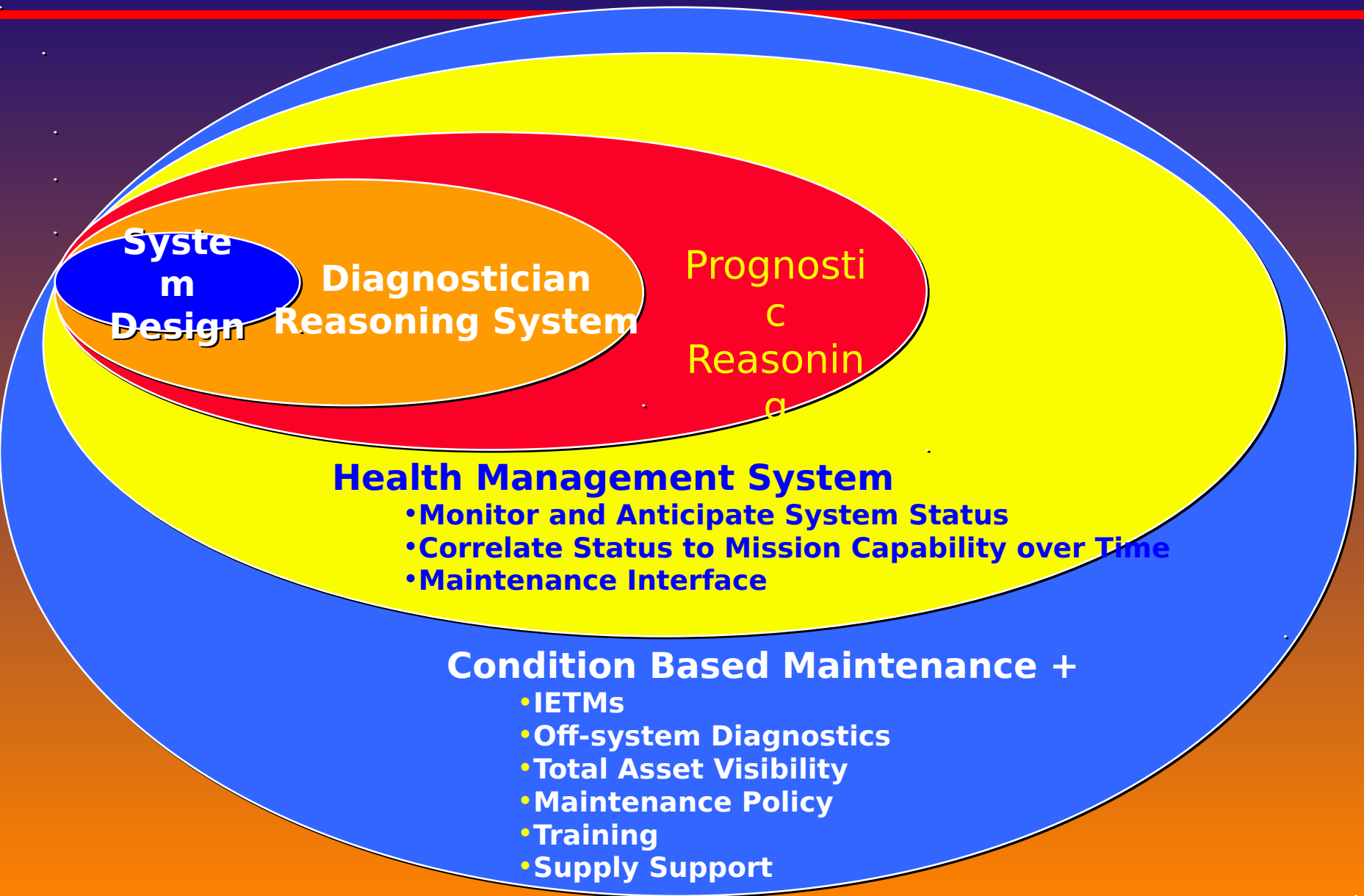
- **Warfighting capability made up of federated systems**
- **Systems are often not integrated; but impact the successful operation of other systems (these interrelationships are specific and definable)**
- **Overall System Health, and Mission Capability, Capacity and Readiness are not readily available**
- **System interrelationships and status are elusive**



Current Posture

- **We Operate in a Data Rich - Information Poor Environment**
- **What can be INFERRED from myriad, diverse data???**
- **We need a network of expert engineers to interpret the data**
- **This network must fit in our back pocket!**

Overall Concept



Diagnostician

- ***Model-Based Diagnostic Reasoning Technology***
 - Uses design-based model for diagnostics
 - Reasons by inferring the implication of myriad data
- ***Dynamic Diagnostic capability***
- **Reads sensor data, built-in test and operational data and performs fault isolation.**
- **Can be embedded or off-line**
- **Results in dramatic improvements in diagnostic accuracy and reductions in troubleshooting time**
- **Extended to Prognostics Reasoning**

"Smart" Diagnostics

DIAGNOSTICIAN

(BIT, IETM, TPS)



Derived from the design of the system!

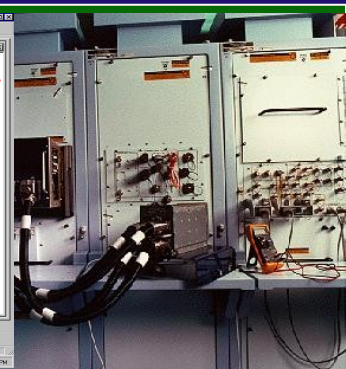
Diagnostician is a set of "reasoning" algorithms that correlate all possible faults to all possible symptoms, or test results to provide fast, effective fault isolation.

- * *Dynamically* bases its determinations based on a snapshot of current fault possibilities.

Knowledge Base Replaces Fault Trees

- Knowledge Base with Inference Engine Reads Event/BIT Data and identifies fault.
- Object Oriented enables Client-Server Integration
 - * Integrated Diagnostics
 - * Integrated Training
 - * Integrated Maintenance
 - * Integrated Data Collection

Diagnostician Applications



Health Mngmt System, Operator Debrief, IETM, Test Program

Sensors, BIT, Operator Observables
BIT, All Observables, O-level test

O-level repair or troubleshooting
O-level repair

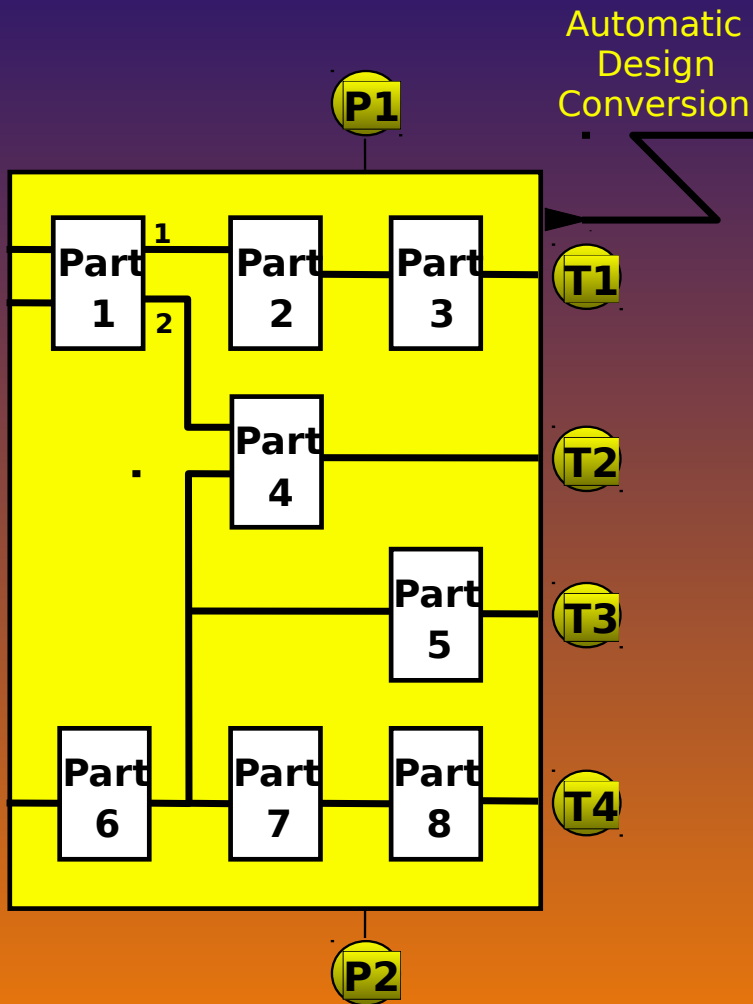
DIAGNOSTICIAN

Diagnostic Knowledge Base

- ✓ System design & faults
- ✓ Diagnostic test coverage
- ✓ Repair information

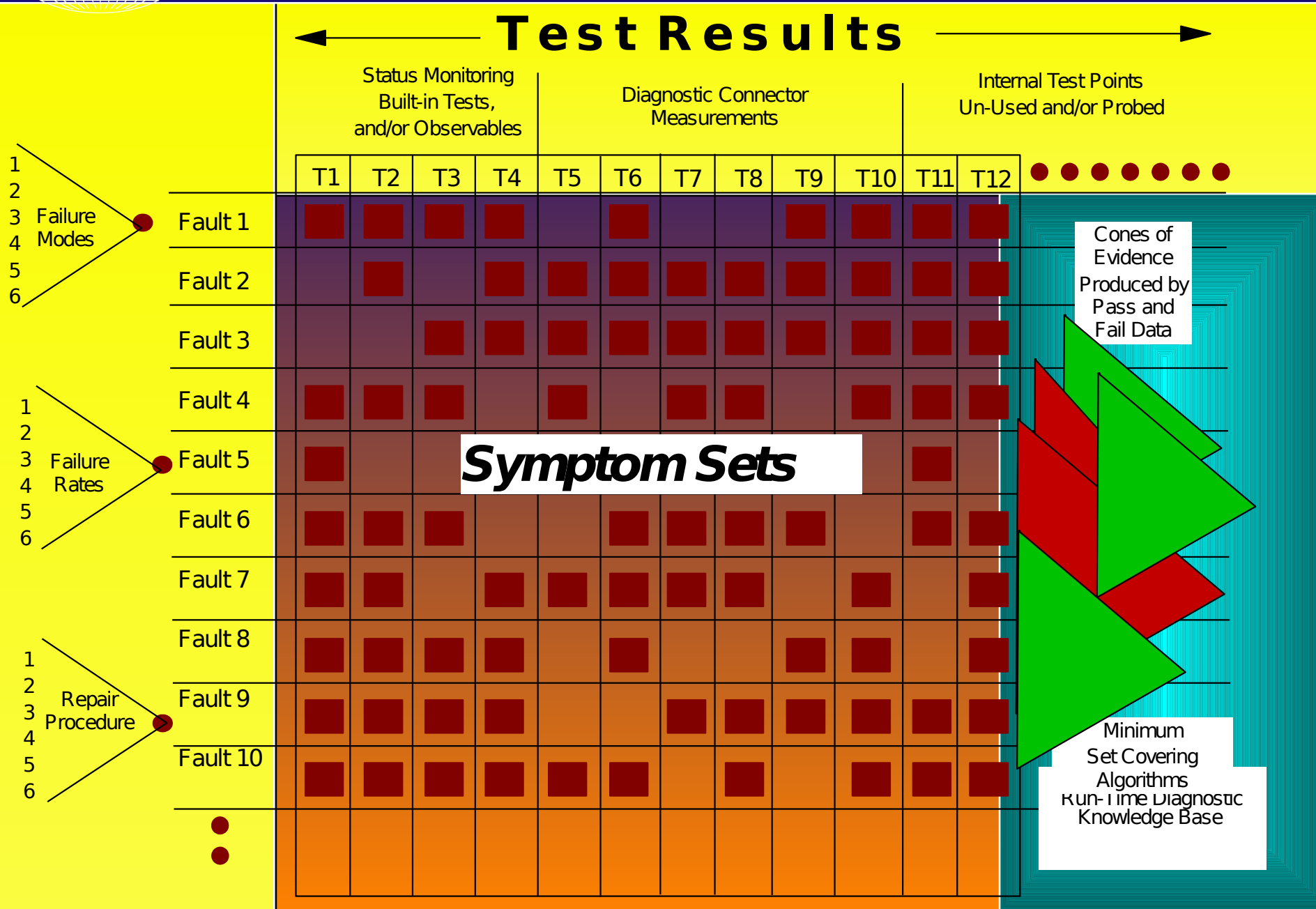
Diagnostician is a set of reasoning algorithms which operate with a system's design information to provide "Automated Diagnostics" to an

System Design Fault/Symptom Matrix



TESTS FAULTS		T1	T2	T3	T4	P1	P2	Test Coverage
Part 1	Output 1	X				X		
	Output 2		X					
Part 2	Output 1	X				X		
Part 3	Output 1	X						
Part 4	Output 1		X					
Part 5	Output 1			X				
Part 6	Output 1		X	X	X		X	
Part 7	Output 1				X		X	
Part 8	Output 1				X			
Fault Propagation								↓

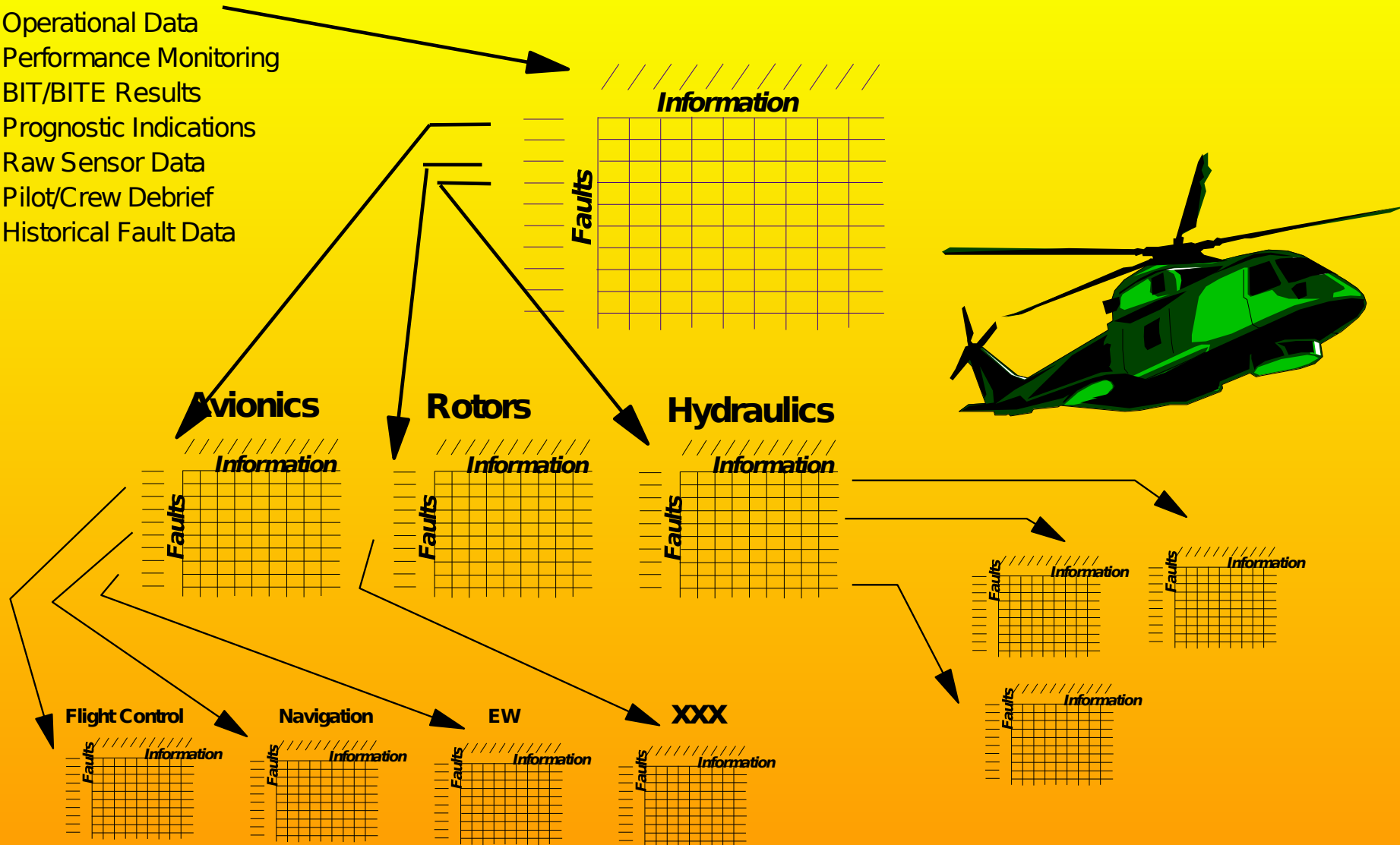
Fault/Symptom Matrix



Diagnostic Prognostic Reasoning: Correlate All Data Across System Hierarchy

INFORMATION:

- Operational Data
- Performance Monitoring
- BIT/BITE Results
- Prognostic Indications
- Raw Sensor Data
- Pilot/Crew Debrief
- Historical Fault Data



Embedded Diagnostics Deficiencies

- **Most Built-in Test (BIT) designed to support operations, not maintenance**
 - **Focus is on Fault Detection at function level**
- **BIT under-accessed / under-utilized in field maintenance**
 - **Reporting to higher system levels involves dilution of content**

Solution is Available TODAY!

- **Diagnostician is an excellent way to put BIT into the "Maintenance" Realm**
 - **Same BIT resources - coverage "mapped" across knowledge base**
 - **Results in Fault Isolation!**
- **Extends Built-in Test (BIT) to Built-in Diagnostics (BID)**

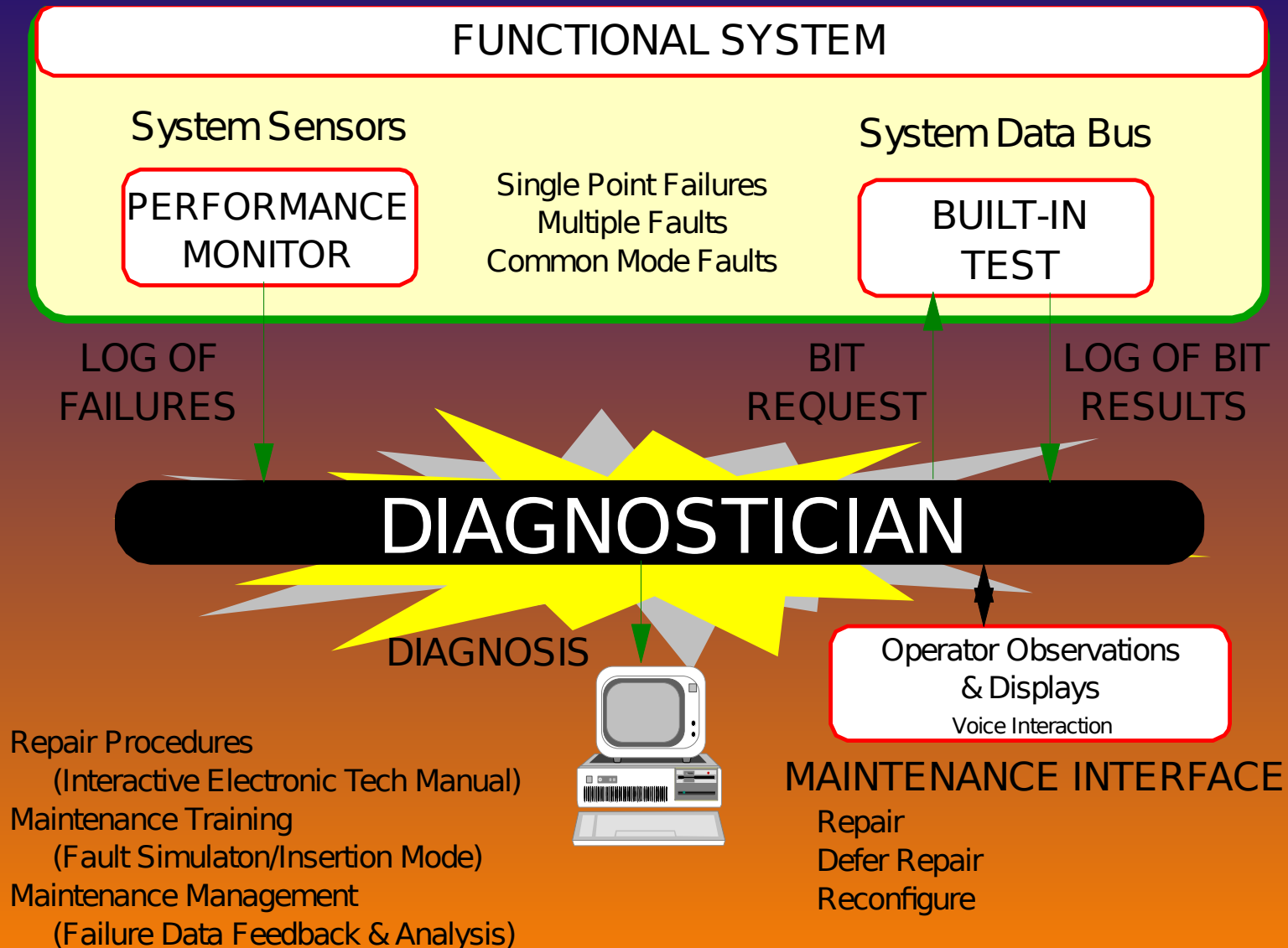
Improved Diagnostics BIT Augmentation

- **Diagnostician Enables Interpretation of BIT at Component Level (much more granular)**
- **Transitions Functional Fault Detection to Component Level Fault Isolation**
- **Can be used in Centralized or Distributed Implementation Strategy**
- **Can be hosted on existing embedded processors**
- **On-line, real-time fault isolation**
- **Structured Functions for Data Logging and Run-Time "Smartening"**
- **Can Report Results to On-Line systems or Off-Line PMA to drive IETM**

Embedded Diagnostician applied to system's BIT with excellent results!

- **F-15 Radar (Hughes Radar)**
 - Additional usage of Calibration Tests for Diagnostics increased automated Fault Isolation to single replaceable item at the O-Level from 76% to 95%
- **Seawolf Submarine Ship Control (Lockheed Martin)**
 - Embedded Diagnostics for Ship Control System handled highly complex quad-redundant system, and allowed technician's to perform repair or defer repairs based on criticality
 - Automatically retrieves repair appropriate procedure and spares info
- **GPS Subsystem (Rockwell Collins)**
 - Embedded diagnostics increased isolation capability from 1 to 2 cards down to group of components for all faults.
- **NASA Remote Power Controller (Boeing)**
 - Diagnostician on a Chip caused fault detection, isolation and recovery within 60 milliseconds so that power not lost to critical applications
- **Future Combat System Gunmount Diagnostics and Prognostics**
 - Changes operating parameters to AVOID failure situations
 - Automatically slows rate of fire to prevent jamming

Embedded Diagnostician



Why the Army Invested in Prognostics Framework

- Prognostic Mechanisms are at various stages of maturity; system-level implementations do not exist
- Army Policy regarding embedded diagnostics, prognostics and anticipatory maintenance is outpacing technology capability for many system aspects
- Point Solutions are Expensive and Risky
- Generic, Tailorable Approach will save time, money, and program-specific funds
- Fastest way for Army to *converge* on Prognostics capability
- Tie-in to logistics infrastructure is critical (e.g., IETM, CSSCS, ULLS, GCSS-A, FSB, FBCB2, ALOC)
- Prognostics should be integrated with Diagnostics to provide a total "Health Management Capability"

What is the Prognostics Framework?

- **A generic, structured information architecture and tools to implement a health management capability**
- **Development and Run-time Tools**
 - Supporting systematic development and integration of diagnostics / prognostics
- **Enables PMs to Converge on Prognostics as technology evolves**
- **Can be applied to existing and new systems**

What is the Prognostics Framework?

- **Integrates Diagnostic and Prognostic into a Health Management System**
 - Maximizes embedded diagnostics
 - Makes maximum use of existing Sensor/BIT data
 - Detailed Mapping of System Interrelationships and Interdependencies
 - Performs Prognostic Analysis/Reasoning
 - Able to Integrate External Prognostics Mechanisms
 - Automatically Logs Historical Data

What Does the Prognostics Framework Do?

- **Integrates Diagnostic / Prognostic Mechanism Outputs From Many Subsystems**
- **Provides Prognostics Analysis / Reasoning**
 - **Monitors Degradation of Signals / Measurements over time**
 - **Depletion of Consumable Items**
 - **Accumulates Wear Factors**
 - **Engineering Correlations**
 - **Tracks PMS based on Wear / Use factors as well as time**
 - **Serial Number Tracking of high-end components**
- **Allows for integration of complex algorithms and functions**
- **Compiles, Interprets and Displays trend data**
- **Links to Tech manuals, PMCS, Supply, etc., based on specific fault or equipment condition**

How does the Prognostics Framework reason?

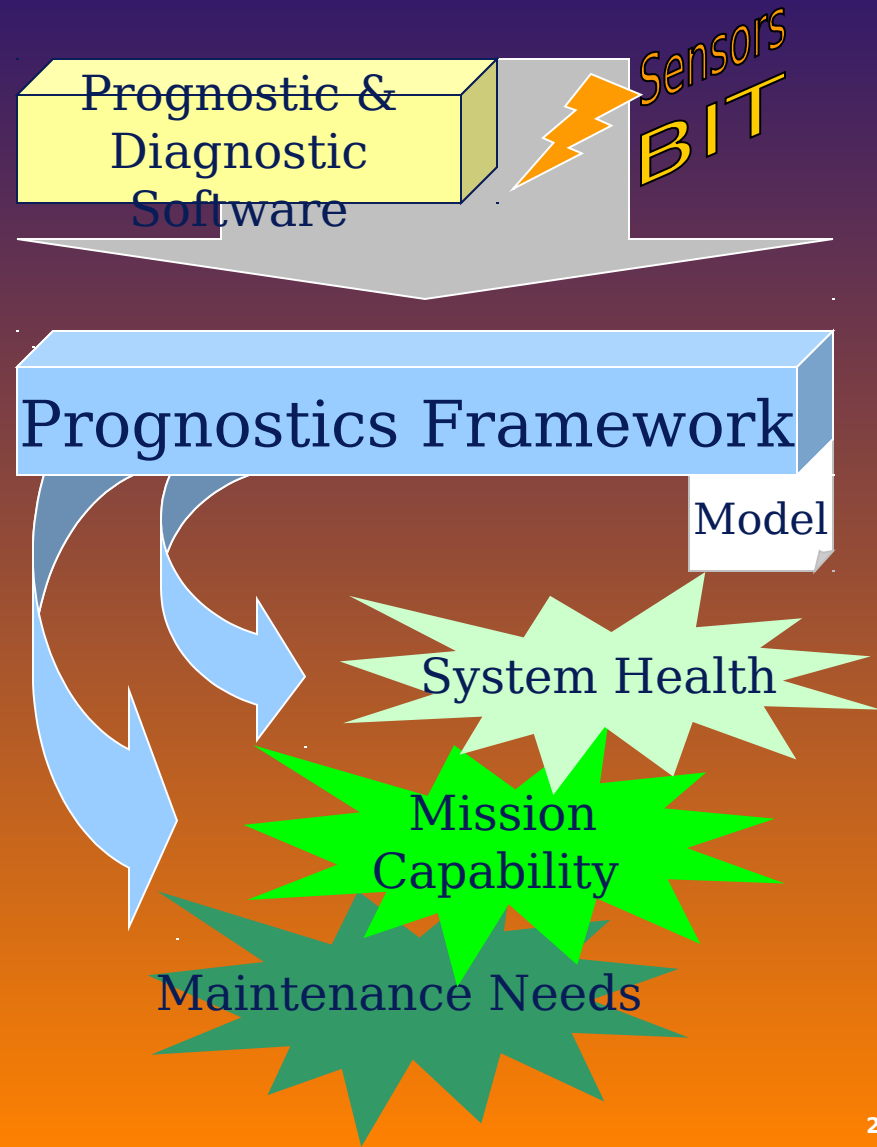
Accept operational data, sensor, BIT and parametric data as *symptoms*

Apply reasoning algorithms to predict & diagnose the implication of out of tolerance *symptoms* on each future time point defined in the model

Identify the components and sub-systems affected by predicted failures - *sub-system health*

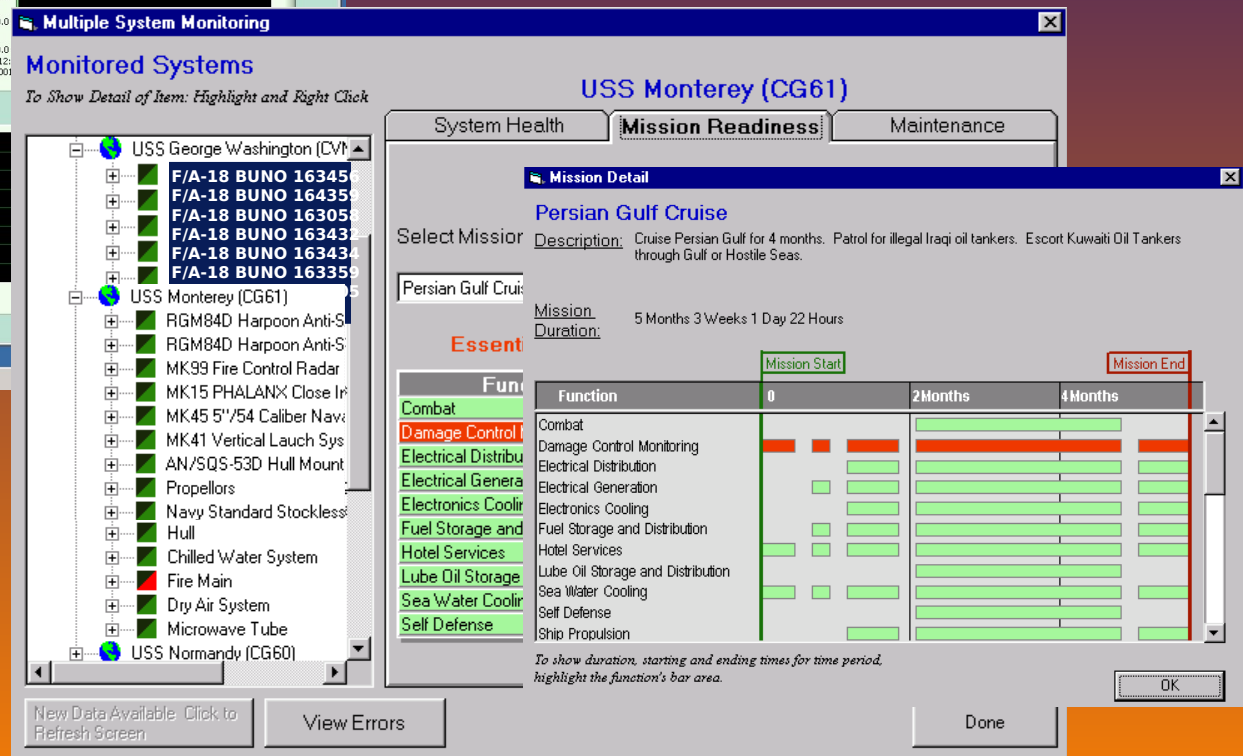
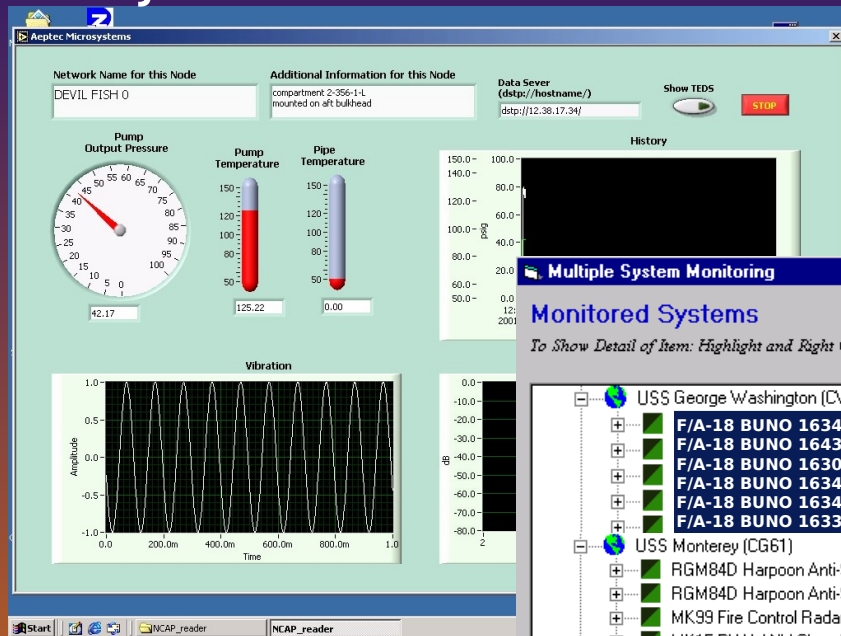
Identify the functions and missions affected by predicted failures - *mission readiness*

Identify the repair actions needed - *anticipatory maintenance*



Not just sensor data.....

....but also mission readiness based on status of inter-related systems



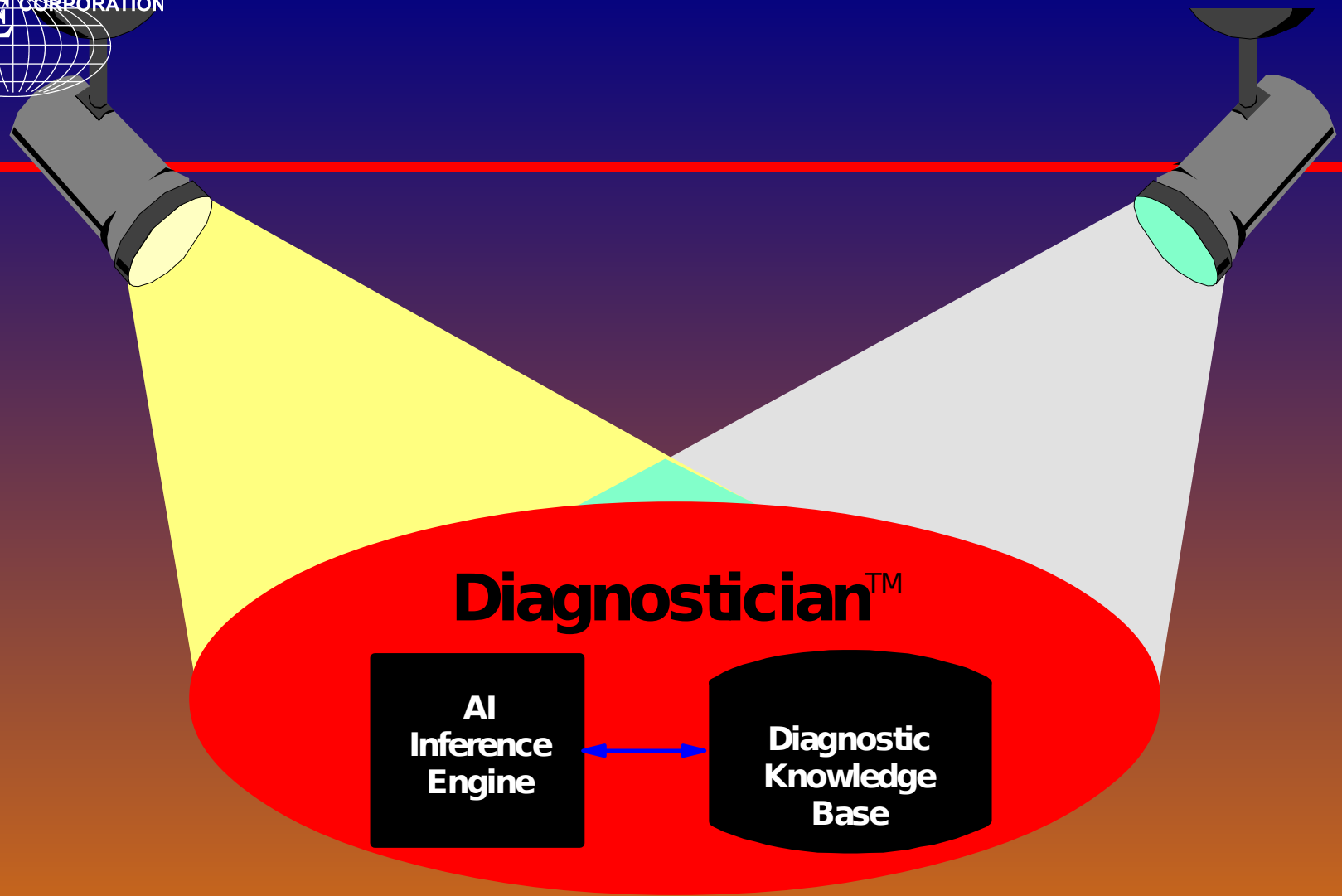
What the Prognostics Framework

Can Do for YOUR System

- Allows you to optimize your system's diagnostic and prognostic capability
- Provides you with Generalized Information Architecture, development tools and run-time software to implement Health Management System
- Maximizes the use and effectiveness of BIT/BITE information
- Provides a divide and conquer approach
- Framework allows you to CONVERGE on prognostic capability as applications and

Benefits

- **Generically Applicable Diagnostic/Prognostic Capability**
- **Enhanced and Integrated Health Management Capabilities**
- **Converts Data to Information**
- **Results in “Network of Expert Engineers” Deployed with System**
- **Customer Ownership and Control of Diagnostic Data**



Diagnostician implementation represents a systems engineering approach.... a methodology ... a program strategy for getting a handle on diagnostics evolution... a concurrent engineering approach to diagnostics ... integrated product development..